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VOL. XIX MAY No. 3

ON THE VARIATION OF IONIZATION IN THE ATMOSPHERES OF VARIABLES OF THE δ CEPHEI AND ζ GEMINORUM TYPES.

BY F. HENROTEAU

The variation of spectral class in Cepheid variables is a well recognized feature. A special study of this property was made by Dr. Harlow Shapley at the Mt. Wilson Observatory, from objective prism spectra made with a 10-inch photographic telescope. In an important paper he gives the variations in spectral type of twenty Cepheid variables.[1] All the stars investigated show that they are of earliest spectral class near maximum light and of latest spectral class near minimum light. The brightest Cepheids, such as δ Cephei and η Aquilae, have been studied in Shapley's paper but ζ Geminorum has not been given.

A number of excellent slit-spectrograms having been secured at the Dominion Observatory, it was thought that an accurate method of estimating the variation of spectral class or variation of ionization in the star's atmosphere could be found. After scrutinizing the spectra, there was found a close pair of lines, one belonging to ionized titanium at λ 4534.139 and the other to neutral titanium at λ 4534.953, which gave promise of furnishing good estimates of the ionization in the star's atmosphere. One line, at times practically twice as intense as the other, at other

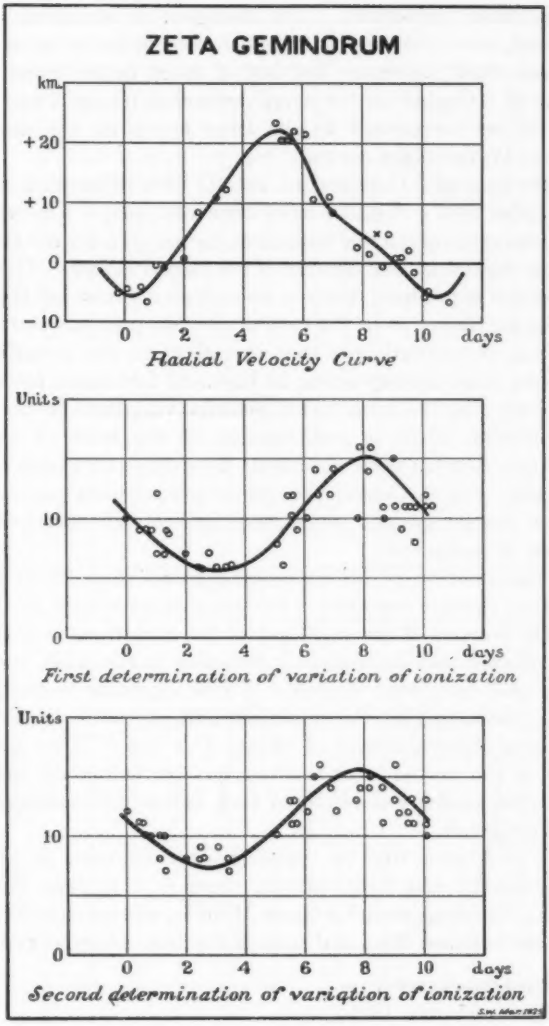
[1] Ap. J., Vol. 44, pp. 273-291; 1916.

times becomes much weaker. The ratios of their intensities were estimated on all the spectrograms of δ Cephei, η Aquilae, ζ Geminorum and α Ursae Minoris. Before being examined the spectrograms of each star were thoroughly mixed, so as to avoid knowledge of what to expect. Each series was examined the same morning and several days later the estimations were repeated for ζ Geminorum and δ Cephei. The spectrograms of η Aquilae, ζ Geminorum and α Ursae Minoris were all taken on fine grained Seed 23 plates, while coarser Seed 30 plates were used for δ Cephei. The values of the ratio mentioned above are plotted according to phase on the accompanying figures; these figures also show the radial velocity curves obtained from the same spectrograms. It must be remembered that for all these stars the maximum light coincides very nearly with the maximum velocity of approach and the minimum light with the maximum velocity of recession.

The curve for δ Cephei shows a minimum of ionization near minimum light and a maximum of ionization near maximum light. The minimum ionization occurs a little before the maximum radial velocity of recession, just as was shown by Dr. Moore in the case of the light curve compared with the radial velocity curve.[2] A remarkable feature is that the ionization decreases rapidly after its maximum; this is in agreement with the curve of spectral variation of δ Cephei published by Dr. Shapley (fig. 1 of the article mentioned above). It may be remarked that the light curve obviously depends on conditions in the photosphere, in conjunction with absorption in the upper atmosphere, while the variation of ionization in question is a function of conditions in the reversing layer.

The curve for η Aquilae also shows close correspondence of its maximum and minimum with those of the light curve. The minimum ionization precedes the maximum velocity of recession more than in the case of δ Cephei; no doubt this is the case with the light curve, for Wylie's photo-electric light curve[3] shows a short branch of smaller inclination than our radial velocity curve, while Wright's figures[4] show an appreciable advance of the minimum light on the maximum radial velocity of recession. In the case of the maxima of ionization, light and radial velocity of approach,

[2]L.O.B. Vol. 7, p. 157.
[3]Ap. J. Vol. 56, 1922, p. 225.
[4]Ap. J. Vol. 9, 1899, p. 63.


ZETA GEMINORUM
km.
+ 20
+ 10
0
− 10
0 2 4 6 8 10 days
Radial Velocity Curve
Units
10
0
0 2 4 6 8 10 days
First determination of variation of ionization
Units
10
0
0 2 4 6 8 10 days
Second determination of variation of ionization

there is closer agreement. The decrease of ionization, at first very rapid, as in the case of δ Cephei, soon stops as far as the observations show (these are few but of much better value than in the case of δ Cephei) in the neighborhood of phases 2 and 3 days. These phases correspond to the large hump on the descending branch of Wylie's light curve.

In the case of ζ Geminorum, results very different from those of δ Cephei and η Aquilae have been obtained. The minimum ionization occurs about one quarter of the period after the maximum light, the maximum one quarter of the period before. The change of ionization is gradual; there is no sudden rise and fall before and after the maximum as in the case of the two previous stars.

It may be noticed here that according to the writer's recent researches, lines corresponding to high and low levels in the sun's atmosphere give the same radial velocity variations in the case of ζ Geminorum, while in confirmation of the work of Professor Rufus,[5] in η Aquilae these variations are different for lines of different levels. For δ Cephei the spectrograms were poorer, being taken on coarser grained plates, and lines of different levels have not been investigated.

An examination of all the spectrograms of α Ursae Minoris shows that there is certainly a variation of ionization in this case also. On account of the smallness of the variations in brightness, radial velocity and ionization, correlation is naturally somewhat difficult and not very certain. Three separate investigations, however, indicate that the minimum and maximum of ionization are situated approximately at phases $1^d.2$ and $3^d.2$, or about one quarter of the period after and one quarter before the maximum light. This result[6] was obtained long before ζ Geminorum itself was investigated.

It is thus seen that in variation of ionization, as in radial velocity curves and light curves, there is a marked similarity between ζ Geminorum and α Ursae Minoris, and an equally marked distinction between them and stars of the true δ Cephei type.

Dominion Observatory,
Ottawa, March, 1925.

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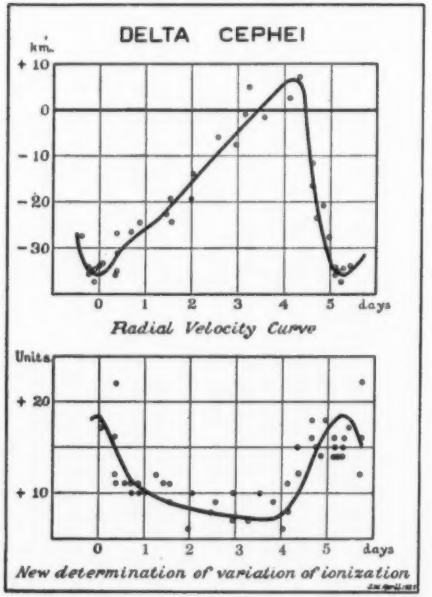
[5]Proc. Nat. Ac. Sc. of the U.S.A. Vol. 10, 1924, p. 264.
[6]Dom. Obs. Publ. Vol. 9, No. 1, Chapter VI.


DELTA CEPHEI
km.
+ 10
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- 10
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0 1 2 3 4 5 days
Radial Velocity Curve
Units
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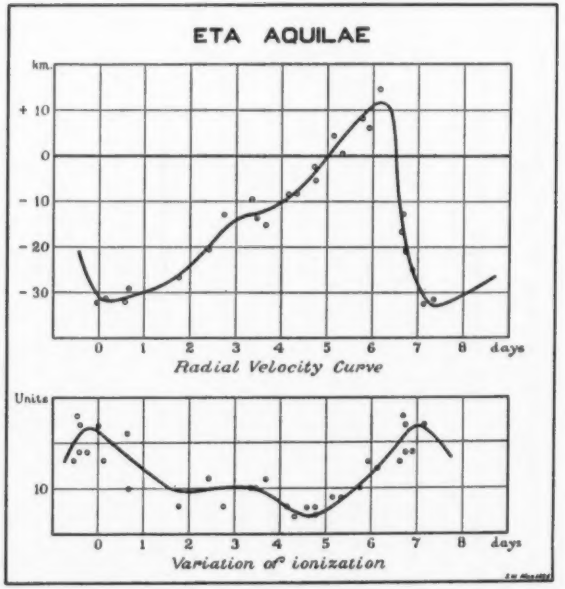
New determination of variation of ionization


ETA AQUILAE
km.
+ 10
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0 1 2 3 4 5 6 7 8 days
Radial Velocity Curve
Units
10
0 1 2 3 4 5 6 7 8 days
Variation of ionization

*THE STORY OF THE EARTH

By R. G. Miller

I think it well to admit that much, and indeed, perhaps, all of what I have to say to-night is not the result of any original research work on my part,—for who, indeed, busily engaged in merely making a living, in a world so strictly governed by the law of the survival of the fittest in the struggle for existence, has either the time or the talent to devote to original research. Moreover, of course, there are other things the average man wants to study besides science, Art, Literature, History, Political and Social Economy, and so forth, and indeed, for most of us there is much work to do and little time to study anything.

It is not given to all of us to be experts in science, but still, notwithstanding any lack of technical training, I think we all must or should cultivate what Bertrand Russell calls the critical attitude and the scientific habit of mind. The habit of weighing, examining and criticising the evidence on any subject, and accepting or rejecting it as it appears to us to be sane, reasonable and logical, or otherwise.

Again, to quote Bertrand Russell, we have had in recent years a brilliant example of the scientific temper of mind, in the theory of relativity and its reception by the world. Einstein, a German-Swiss Jew, was appointed to a research professorship by the German Government in the early years of the great war. In 1915, I believe, to be exact. As a result of his studies he came to certain conclusions and made certain predictions, which have since been verified in greater part by various scientific expeditions sent out for the purpose. His conclusions and theories, I believe, upset the whole framework of traditional physics, and are about as damaging to orthodox dynamics as Darwin was to Genesis, yet physicists the world over, irrespective of race, creed or national-

*A lecture delivered before the Victoria Centre, R.A.S.C., Tuesday, March 17, 1925

ity have shown a complete readiness to accept his theories as soon as it appeared to them that the mass of the evidence was in favour of his conclusions. But none of them, and at least of all, Einstein himself, I am quite sure, would claim that he had said the last word. There are problems he cannot solve, and difficulties which he has not been able to overcome, and his doctrines will have to be modified in their turn as his have modified Newton's.

This critical undogmatic receptiveness is what I understand and respect as the true and traditional attitude of science.

I propose then to give you to-night, as well as I can, and as far as I may, in the time at our disposal, a brief synopsis of the story of the earth, and to consider some of the theories as to its origin, its evolution and its climatic revolutions.

The story of the earth is one of the longest and oldest stories of which humanity knows, yet it is one of the most recently discovered and least perfectly learned. Two or three thousand years ago men knew nothing about it, and would have been unwilling to believe it if told—nay more, they would have resented it with vigour and physical violence. Two or three hundred years ago they knew a little—a little of the history of the preceding three thousand years or so, and a few hints as to what might have taken place in ages and centuries earlier, but none of them suspected that for each of the decades they allowed, man would some day allow a thousand centuries.

Gradually, however, such calculations based on dogmatic interpretations of old legends and traditions of various sorts, ceased to represent the best of knowledge on the matter. The conception of the universe, or even that tiny part of it we call the earth, as a matter of only a few thousand years standing has at last, and finally I think, gone by the board.

Let us consider some of these newer ideas. The ancients thought the earth a magnificent body, quite independent, and with a number of celestial hangers-on, whose principal duty it was to furnish light, heat, and inspiration to poets. To-day we know that the earth is a very small part of a very great system—the Solar system. That system in turn, is but a very small part of a still greater one in which there are many suns which we are accustomed to call stars—uncounted millions of them in fact. This

great aggregation we call the universe. If we wish to be more exact we call it the Sidereal Universe, to distinguish it from other universes, sometimes called Island Universes, indicated to us by the presence in the heavens of spiral nubulae. These spiral nebulae are very far away from even the most distant star, so very far away, indeed, are they that even the most delicate of astronomical instruments fail to tell their size, their rate or direction of movement, or even their distance from us.

But to return to the earth, one of the smallest and least significant of the heavenly bodies. As every one knows, it is a ball, somewhat flattened at the ends, like an orange or a grape-fruit, and about eight thousand miles in diameter. There is nothing strange about this flattening at the ends or poles. It is there because the earth turns rapidly about—at the rate of about a thousand miles an hour at the equator, and so spreads out towards the middle and flattens at each end.

Of course, we cannot tell simply by feeling or looking, that the earth turns—rather it seems to us that the stars and the sun move round it; and one of the fiercest battles in Christendom was fought over the then heretical thesis that the sun ran the earth rather than the earth the sun, and even to-day reason and science have only but partly won out.

Perhaps it may not be out of place to remark here that it was not until 1543 that the epoch-making work of Copernicus on the paths of the heavenly bodies appeared, which resulted in the placing of the sun and the earth in their true relative positions. His work was amplified and completed by Kepler, Newton and Galileo, to mention only a few of the galaxy of brilliant intellects brought to bear on the subject; but to Copernicus belongs the honour of having formulated and founded, and given his name to present day Astronomy.

There have been and there continues to be a great diversity of opinion as to how and when this globe of ours originated as such. It is the nearly unanimous opinion of Astronomers to-day, I believe, that our Solar system was evolved in some way from a Nebula of some form.

Until recently Scientists so generally accepted the view of La Place, the great French mathematician of the 18th century,

as to the gaseous nebular origin of the earth, that it was known as *the* Nebular Hypothesis. The advance of enquiry, however, made it necessary to consider other hypotheses, which maintain that the Solar system arose from a Nebula indeed, but a Nebula, whose constitution and mode of evolution differed from that postulated by La Place.

The leading hypotheses of the earth's origin, may I think be grouped into four classes—The gaseous, the meteoric, the planetesimal and the collisional:

(1) THE GASEOUS—In which the parent nebula is assumed to have been formed of gases collected into a sphereoid, and to have evolved into the present Solar system by condensation and loss of heat, and later by the separation of the outer parts into planets. This is, in brief, in very brief, the LaPlacian hypothesis.

(2) THE METEORIC—In which the parent nebula is assumed to have been a swarm of meteorites, the members of which moved in diverse directions, and which, owing to frequent collisions, gave rise to heat, light, and vaporization. According to this theory, the earth instead of having shrunk from a ball of gas, much greater than its present size, has been built up from mass, the smallness of which is not determined.

(3) THE PLANETESIMAL—In which the original constitutents are assumed to have been small bodies moving in orbits about a common centre, and forming a disc-like system. These bodies are supposed to have been controlled by revolution about the centre of the nebula, and not by impact on one another. The evolution consisted in the gathering of these small bodies, planetesimals—into planets and satellites.

(4) THE COLLISIONAL—Two stars meeting. Not necessarily head-on impact, but coming so close to each other that the pull of one upon the other produces disintegration, and from this, so to speak, a fresh start is made and a new nebula comes into being. And also the supposition of such things happening is held to account for the presence of "New" stars, which suddenly appear, flame to an intense brightness, then gradually assume their place of respectability in the stellar family, and finally fade away. Or—a great mass is torn by tidal effect from one or the other of two colliding bodies and forms a separate star or sun, which in turn

throws off other rings or fragments, and these in process of time become planets revolving round the central body as in our Solar system.

It may not be exactly apropos of the subject, but I cannot help remarking that I do not remember to have read of any attempt to account for the origin of such bodies moving about in space. Of course, as Dr. Plaskett said in his address, published in last October's *Journal*, we must assume something, postulate something for a start, so perhaps it is hypercritical to go further back.

As far as I am able to judge, it seems to me that we might very well admit not having any too decided an opinion on the subject, considering the state of flux and liability to further change in any hypothesis, and also the possible advent of a newer and perhaps better hypothesis. It may be that planets evolved out of a gaseous nebula would not have sufficient attraction to hold their gases in their earlier stages. One might admit that, and yet admit it with reserve. One might also admit that there are difficulties in all of the hypotheses and that in the present state of scientific knowledge there is no adequate manner in which to account for the relatively contradictory speeds of the planets in their orbits, for the orbits themselves, and for the varying tilts which they all have relative to the sun, or to account for the retrograde motion of some of the planetary satellites or moons.

The enormous gas clouds which astronomers see and photograph in the heavens, may be gatherings together of the ether, whatever that may be. And speaking of the ether, Lord Kelvin considered it to be an elastic fluid filling all space. "It must", says another Scientist (Le Bon), "possess a rigidity exceeding that of steel or it would not transmit luminary vibrations at the rate of three hundred thousand kilometers a second." And yet it has been demonstrated, I believe, that combined with this solidity, it must possess a density a million times less than our atmosphere. If you can imagine a substance more rigid than steel, yet without weight or density, and through which things can pass more easily than through air, then you can imagine the ether. I confess I cannot, and yet I confess that it has to be assumed, supposed, postulated.

But to return again to the earth. The earth is made up of

three general classes of materials—solids, liquids, and gases. The first make up the rocks—the lithosphere, or as we generally call it, the earth, the crust of which, by the way, is estimated to be about sixty miles thick. The liquids of the earth form the hydrosphere, and lie for the greater part in basins and troughs, so as to form oceans, lakes and rivers. The third is made up of the gases, and forms the atmosphere, and this is the part of the planet in which we are submerged to the extent of some five hundred miles, although it is admittedly very difficult to realize this fact.

The question which now most naturally arises is: "Yes, but when did all this happen?" The answer is, I am afraid, rather vague. Anything from 300 million to 1,600 million years. There are differences of opinion, and matters still to be settled between Astronomers, Geologists and Physicists. Personally I incline rather to the more than to the less. As Professor Schofield remarked in a lecture on Geology which he delivered here some two years ago: "When considering such subjects" (having special reference to Geology, of course) "we have to think, not in terms of hundreds or thousands of years, but in millions or billions of years."

The next question which calls for an answer is:—"Has the configuration of the earth's surface remained unchanged since it was first evolved and formed?" Well, the answer to this is in the negative. When we read in scientific works with regard to the inequalities of the earth's surface, that relatively it is as smooth as a smooth-skinned orange—it is rather bewildering to the lay mind, considering the high mountains that we know of, and the deep deeps that we read about. Yet it is so, relatively so, and, of course, we all speak relatively these days.

There have been several drastic changes brought about by various agencies and various means, such as earthquakes and eruptions of lava, but the greatest factors in the changes in the earth's surface have been ice and water. The Ice Ages alone can account for almost all of the earth's surface changes and revolutions in climate. And when I use the word revolution, I do not mean to imply any sudden—short, sharp and sudden catastrophe—such as we generally associate with the word revolution. Measured by

our familiar standards of time, it was still a very, very slow evolutionary process.

This second section of my remarks, as I think I may call it, comes more properly under the heading of Geology—the science which deals with the materials, the make up, and the development of the earth. We know that the hills and the mountains were in existence millions of years ago, but we also know that the sea covered the land, millions of years before the mountains came into existence. And we know that waves beat upon mountains that are now hills, and upon hills which no longer exist. And water will be found ready to advance upon the land when the mountains of to-day are low ridges. It is not the rocks that last, it is the water. The destruction of rocks is one of the most fundamental facts in Geology. It affects the entire surface of the planet, and even the dwellers thereon. Without it we should have no clays and no soil, and the generally accepted opinion among Geologists to-day is that this destruction has been mainly caused by ice, during various Ice Ages.

The knowledge of Ice Ages having occurred during the earth's history is quite recent, and since they have been known, various theories have been advanced to account for them. The first theory which occurred to experts as an explanation was, that possibly the poles of the earth shifted in the course of long, long ages. It was thought that some sort of wobble or lean-over had taken place at some time. In that case the poles would wander. That is to say, the Ice cap would shift from one region to another, as the earth wobbled in space.

The next theory to account for the Ice Ages was based on the assumption that the long ends of the elliptic orbit of the earth became, for some reason or other, so long-drawn-out and away from the sun, as to cause the polar caps to spread towards the equator. This theory is now also generally abandoned. Nevertheless it is the theory which was long held by Astronomers. Even such an able man as Sir Robert Ball adhered to it during most of his life, but abandoned it at last because of the overwhelming evidence in favour of the geological theory. The chief difficulty about this theory was that there would have been frequent and periodic Ice Ages, whereas it is now generally agreed

that the earth has had only five of them during its long history.

The next cause suggested as an explanation of the Ice Ages is much more plausible. Why is it colder at the top of a mountain than at the sea-level. The rays of the sun are just as strong or stronger, because they are less obstructed by the atmosphere. But except in the direct rays of the sun, it becomes colder the higher you go up. Height, as such, has nothing to do with the matter. It is the gradual thinning of the atmosphere as you rise which is responsible for the cold.

And now we come to an explanation of the cause of the Ice Ages. It was the rise in the land, and the changes in the atmosphere involved by this. But then, what was the cause of the rise of the land? Now although it may appear to be a paradox to say so, yet it is the sober truth that the wearing away of high lands and mountains by rivers and rains and so forth was the proximate cause of other elevations, which in process of time became the birth-place of glaciers.

Every one knows that the water—rain, river and waves—is constantly wearing away the land. The rocks are for ever crumbling, and every shower of rain washes away the refuse. Stones are broken into pebbles, pebbles are ground into sand, and the sand is heaped on the sloping bed of the seas.

It has been estimated that the rivers of the United States convey over eight hundred million tons of material from the land to the ocean every year, which means that the United States as a whole loses one inch deep of its surface in 760 years. But multiply eight hundred million tons a year by four or five million years. At the end of that time several thousand billions of tons will have been transferred from one part of the earth's crust to another—in other words, laid upon the sloping shelf which we call the bottom of the sea, near the shore. This causes a very serious alteration of the equilibrium of the crust. The ocean floor sinks steadily under the load. On the land the lighter crust steadily rises. There is a prodigious pressure from the sea towards the land, which is only relieved by the land—that part of it near the shore—rising in giant folds as it presses against the harder masses of the interior, and permitting the molten matter to rise under its folds. Thus, it is believed, have all the great mountain ranges been formed.

It is estimated that this force exerts a pressure of from twenty thousand to thirty thousand pounds per square inch, according to depth.

The next step is the wearing down again of the new mountains, which proceeds rapidly while the land is elevated and the water runs freely. But between the two processes is the interval with which we are concerned—an Ice Age. This lasts from a quarter to half a million years, it is generally estimated. It reduces the mountains to a level at which glacial conditions no longer occur. The great floods of the melting ice in their turn, do a vast amount of scouring. The eternal hills vanish once more, and the earth returns—or did in earlier ages—to its warm lowland condition, until another crisis in the crust appears.

Geologists are in substantial agreement as to the fact that there have been in all five great ice ages, and that the interval between them seems to be about fifty per cent. shorter after each Ice Age. We are very uncertain what was the whole period of time taken to form the crust of the earth. Schuchert, one of the ablest of modern geologists, considers that geological time endured about eight hundred million years. But lately Baron Rayliegh and the physicists have been insisting that the story of the earth is a matter of at least sixteen hundred million years.

After each Ice Age the earth returns to a genial climate, but not to the temperature it had before. The globe is steadily growing colder. Ice Ages are temporary periods of intense cold for certain parts of the earth, but, and apart from that, the globe as a whole is running down as it were in point of temperature.

Until the oncoming of the last Ice Age there was no such thing as really permanent ice and snow anywhere on the earth. Now the poles are permanently frozen over, and as time goes on—as millions of years go on—the ice will slowly extend towards the equator. Even what we know as the polar regions—Greenland and Iceland included—covered, as we say, with eternal snow and ice—had at one time a climate which was intensely tropical. They have extensive coal-beds which are simply the remains of vast tropical forests, and bones and fossilized remains have been found in these regions belonging to a class of animal which could only have flourished in a warm humid climate.

There is a somewhat exaggerated idea of the fall of temperature needed to create an ice age, but there is a general agreement that an average fall of 10 degrees in the temperature of a continent would cause an ice age. It is not difficult to see how a great rise of the land would bring about a change to this extent in the temperature of a whole continent.

Geologists divide time into eras, and each of these is subdivided into periods. Each represents a certain group of rocks, the thickness of which is fairly well known—so that, allowing for different rates of formation at different times, they, roughly at least, know the length of one era as compared with another. There are five of these eras, and if we represent the whole thickness (the whole of geological time) as 100, the proportion of each era is as follows:

Cenozoic Era	5	Estimated duration forty million years.
Mezozoic Era	12	" " one hundred million years.
Palaeozoic Era	28	" " three hundred million years.
Proterozoic Era Archaezoic Era	55	These two are generally classed together and called the Archaen or Ancient Era, and they are estimated to have lasted a thousand million years.

The last Ice Age was at the end of the Cenozoic Era which ended about thirty thousand years ago. The other day so to speak. The previous great chill at the end of the Mezozoic. The one before this at the end of the Palaeozoic, and the preceding one at or before the beginning of the Palaeozoic. So far for four Ice Ages it is certain that the interval has been reduced by about fifty per cent. each time. There remains only one, the first Ice Age, and here estimates are somewhat conflicting and uncertain. But it occurred somewhere about the middle of the appallingly long era known as the Archaen.

This is a singular phenomenon. It not only suggests that the earth will be permanently covered with ice and snow in a few million years, because the interval between Ice Ages will shorten until the intervals disappear altogether, but it makes one suspect a machinery which is unknown to us. There is a sort of rhythm about it which excites curiosity. It is agreed too, that the abysses

of the ocean are becoming deeper as time goes on, and that the land is much higher than it used to be. The earth seems to require to adjust itself to these changing conditions from time to time, and appears to do so not continuously, but by mighty spasms of mountain making at long intervals, and these give us our revolutions of climate.

The first or Ancient Era represents more than half of the earth's story. The rocks of this age are moreover overwhelmingly volcanic. They represent tens of millions of years of constant and prodigious outpours of lava upon and through the thin crust. This is what we should expect, precisely because the crust was thin—thinner than now—and the heaping up of mass upon mass of lava in time produced an altitude sufficiently high to give the required temperature for a first Ice Age.

Having now given, (again in very sketchy form indeed), the story of the earth's revolutions, it seems to be no exaggeration to give that name to an Ice Age. Between each of the older geological eras was a revolution physical and biological, and the somewhat obscure Archaen Era also witnessed an Ice Age. That there were also biological as well as physical changes is now pretty generally admitted, at least by the intelligencia, and what the others think does not really matter.

What effect the first two Ice Ages had upon life we do not know, but the chronicle is very complete with regard to the third, fourth and fifth. It is enough for our purpose to make the statement that the third brought upon the scene, the mammal and the bird, the fourth made the earth suitable for the mammal and the bird, and the fifth in stimulating the evolution of man towards civilization rendered the greatest service of all. Much of this may sound like romance but it is a very sober romance, and remembering the fifty per cent. shortening of intervals already suggested, the inference as to permanent glaciation is pretty conclusive. Not a very cheerful ending perhaps, but be not alarmed—it is not yet. Estimates on this point are also very wide. Anything from three to eighty million years.

With regard to the beginnings of life upon earth, the key to the puzzling story is as usual, the physical story of our globe, and the evolution of all living things is, and has been conditioned by changes

in the physical world which cannot reasonably be connected with any plan. For aeons, the immensity of which overwhelms man's conception, the earth was unfit to maintain what we call life. It is now covered with visible living things which are not formed of matter different from that around them. They are on the contrary, bone of its bone and flesh of its flesh. As Huxley said, some time ago it is true, but as true now as it was then— "If it "were given to me to look beyond the abyss of geologically recorded "time to the still more remote period when the earth was passing "through physical and chemical conditions which it can no more "see than a man can recall his infancy, I should expect to be a "witness of the evolution of living protoplasm from not living "matter."

Such then, as I see it is the story of the earth, stated in one word, Evolution. Nature and all things in nature have grown during tens or hundreds of millions of years to be what they are. They have been shaped very slowly and very gradually, and have passed through numerous earlier forms. They have been evolved.

What will happen after permanent glaciation does occur, is a very speculative question indeed. It may be re-absorbed into the sun, or perhaps it and the whole Solar system may come to a catastrophic end by collision, and re-form either as nebula or a new Solar system. In any case I know of no reason which has been advanced to assume an ending—a finality of all things—or a beginning. A first cause and a last effect are intellectual chimeras.

As Shelley so finely puts it in four lines of poetry, and, as is usual in good poetry, puts it more clearly and forcefully than could be done in an equal number of volumes of prose:—

> "Worlds on worlds are rolling ever;
> From creation to decay;
> Like the bubbles on a river,
> Sparkling, bursting, borne away."

Victoria, B.C.
Mar. 17, 1925.

REPORT ON THE TOTAL SOLAR ECLIPSE OF JANUARY

In continuation of the reports of various observers on the eclipse of January 24, Mr. A. B. Turner viewing the eclipse near the eastern end of its path in the United States writes:

"Our party from the College of the City of New York, consisted of Prof. A. Bruckner, Prof. G. C. Autinrieth, Mr. Robt. Wolff and myself. We occupied a farm near New Fairfield, Conn. just above the central line of totality (Lat. N. 41° 29′ 27″; Long. W. 73° 30′ 42″). The main object was to observe the shadow bands near the central line. We had a beautiful surface of snow upon which to observe the bands. Light rods about eight feet long graduated in feet and inches were used to get the direction of motion of the bands. Each observer had two of these—one of darker wood to to be laid in the direction of motion, and one of lighter wood to be laid along the crest of the bands. I had a second set, independent and some distance from the first, to use for observation after totality. We thus had four independent sets of rods at some distance apart. The following results for the direction of motion were obtained.

	Direction of Crests		Direction of Motion	
	Before	After	Before	After
Autinrieth	N.27°W	.....	S.63°W.	.....
Bruckner	.....	N.27°W.	.....	S.28°W.
Turner	N.26°W.	N.27°W.	S.63°W.	S.63°W.

Mr. Wolff acted as time-keeper.

Directions are with reference to the true north and south.

The computed direction of the moon's shadow was found to be S.73°E., which would indicate that the bands were not moving at right angles to the direction of motion of the shadow. At the time of the eclipse a small, very filmy cloud was between us and the sun which may have affected the appearance of the shadow bands as they were very much more distinct after totality, when the cloud had thinned out, than before. (They were certainly not so sharply defined as those of the eclipse of May 28, 1900, which I remember vividly).

Report of Professor A. Bruckner:

The pre-eclipse shadow bands; observed on a snow bank, not very distinct. Like the shimmering of heat waves uncolored. Difficult to distinguish between the direction of the crest and the direction of motion of the crests. That is, there was a sensation of something moving. I did not succeed in becoming certain as to whether the apparent motion to me was the real direction of the motion of the crests or the apparent motion along the crests due to the wavering of the crests.

The post-eclipse bands, also observed on the snow bank, were much more distinct than the pre-eclipse bands, the direction of motion was beyond doubt, the bands uncolored and about nine inches wide.

Report of Professor G. C. Autenrieth:

The shadow bands appeared to me in groups. Each band was about ¾ to 1 inch wide with an amplitude of 12 to 14 inches. Each group was made up of fairly deep bands and a number of lighter ones separated at spaces approximately equal to band width. The deep bands travelled about 12 to 14 inches per second. The bands appeared at least one minute before totality, and lasted almost two minutes after totality. The latter bands became clearer and the velocity was judged on the second appearance. The direction of crests and motions approximately the same after totality as before.

Report of the Observations of Mr. W. C. Bettinson of the N.Y. Telephone Co., at Upper Montclair, N.J.

We entered the Valley Road Gate of the Mount Hebron Cemetery, following the path to the left until we reached Kelly's Tomb (a granite monument) situated about 500 feet from Valley Road and about 700 feet from Mount Hebron. We stood on the path about 2 yards beyond the tomb and commanded a good view of the valley in front.

Light waves appeared just before and after totality. The bands pointed Northeast to Southwest, and seemingly travelled

from the Southeast to Northwest*—or at right angles to the direction in which they were pointing. They were straight bands, vibrating vigorously and travelling rapidly.

On the snow the bands appeared about an inch wide edged with silver. On the side of the tomb (which is about ten feet high) they were just shadows running obliquely upward, about an inch wide near the ground, gradually widening to two inches near the top. As they gained breadth, they lost density.

Mr. J. R. Collins suggests the following observations that might be made during a total eclipse, especially under cloudy conditions:

1. Note and classify the cloud formations near the sun immediately prior to first contact.

2. The character and extent of changes in cloud formations during the time of eclipse from the first to fourth contact and compare them with number one.

3. Note beforehand the position and angular extent the approaching shadow cone should present to the observer and compare with that actually observed.

4. Direction and velocity of the wind before, during and after the eclipse, and whether the intensity dies down and springs up again after totality.

5. Note if the flash at time of second and third contacts illuminates the sky at your station, and if it can be observed as flashes along the edge of the approaching and receding shadow cone.

6. Note from high elevations at points across the path of the shadow, the apparent direction of approach of shadow.

7. Whether the intensity of the light is greater immediately after or before totality. Whether the light at second and third contact increases in a uniform manner or comes and goes in pulses.

Some of these observations can only be made during a *cloudy* eclipse.

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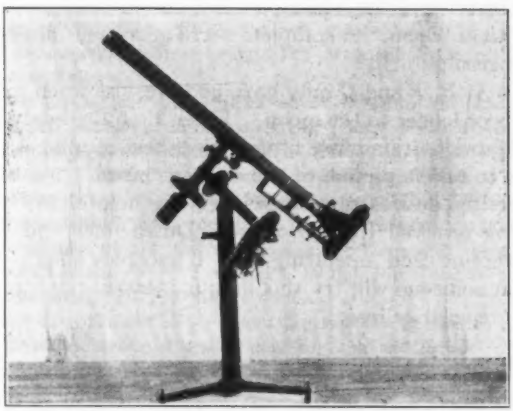
*I have verified the direction of motion to be approximately N. 16° W. The ceme ery was about one mile inside the path of totality. Other observations made by friends on the edge of the shadow were very conflicting and indefinite. They seemed unable to distinguish direction of motion from direction of the tangent line to the crests.

A. B. TURNER.

Mr. Robert Ellms, writing from Smith College, Ohio, describes a small camera which he constructed for use at the eclipse which may be of interest to amateurs of the society.

The primary reason for which the camera here described was constructed was to take photographs of the solar eclipse. Professor O. L. Dustheimer, Professor of Astronomy at Baldwin-Wallace College and president of the Cleveland Astronomical Society with about sixty members of this organization conducted an Expedition to Niagara Falls to view and photograph the phenomenon. Due to unfavorable weather conditions the camera proved useless.



While this camera is by no means the simplest that can be constructed, it can be made with but a small outlay of money, labor and material. The main parts involved consist of a small telescope, an ordinary Kodak and driving clock.

In assembling the instrument it was found necessary to remove the eyepiece of the telescope and the lenses of the camera, and to replace these by a double concave lens of considerable strength in order to obtain a clear, sharp image on the film. This idea involves the main principle of telescopic photography, and was suggested by Dr. E. C. Unnewehr, Professor of Physics at Baldwin-Wallace

College. The optical parts were simplified to an objective, a double concave lens and a suitable light filter. The rays of light strike the compound objective, pass through a filter, and then before converging to a point *f*, are made to pass through the double concave lens *C*, which extends the focus of the combination; thereby enlarging the image and giving a good definition on the photographic film.

A 24 hour clock was used to drive the telescope in right ascension. The photograph shows the manner in which this clock was mounted. Instead of using plates an ordinary 116 Kodak film was used. In order to facilitate changing pictures a small hand crank was wired to the semi-ring device of the Kodak.

The objective of the telescope was 5 cm. in diameter, and had a focal length of 90 cm. A complete set of gelatinous filters gave the following results:

Filters *A*, *B*, *F* and *G* only gave good results when exposed for 10 seconds or longer to the moon. Filter 2 required only 5 seconds to give clear definition while filter *C* gave best results. It required 4 seconds to take a picture of the crescent moon.

The writer desires to acknowledge the helpful assistance and suggestions received from Professors Dustheimer and Unnewehr in constructing and operating this telescopic-camera. He also hopes that someone will try this unique inexpensive equipment at some future solar eclipse.

MEETINGS OF THE SOCIETY

At Toronto

The regular meeting of the Society was held on February 24th in the Physics Building with Dr. Chant in the chair in the absence of Mr. Hunter.

The minutes for the last meeting were read and approved.

The following were nominated for membership: O. S. James, 93 Isabella St.; L. M. McKenzie, B.A., Knox College.

Mr. W. E. W. Jackson mentioned that there had been several interesting sun-spot groups during the last week and that the number of small spots was increasing, which would indicate that the minimum period had finally passed.

Dr. Chant showed some photographs of the eclipse taken in England which had been sent to him. He then called on Mr. W. E. W. Jackson to address the meeting, his subject being "The Magnetic State of the Earth during the Solar Eclipse".

Mr. Jackson stated that the results obtained from the magnetic investigations would probably not be of great value, as there was a small magnetic storm in progress which made it difficult to separate out effects due to the eclipse. Also, the observation of magnetic effects is a delicate operation and the quantities to be examined very minute, the diurnal variation in declination during the month of January amounting to only about ten or twelve minutes of arc, the variation in the horizontal force to about 23/100000 dynes and the expected variation in this force due to the eclipse would be of the order of 1/100000 of a dyne.

Mr. Jackson then showed slides comparing results obtained by Mr. C. O. Jones of Welland by means of a thermohydrograph with results obtained at Toronto, readings being taken for several hours before and after the eclipse. The humidity of Toronto decreased steadily until the time of totality, increased for a short time and then continued its downward path. At Welland it increased fairly regularly until totality and then dropped again. In connection with the declination, there was possibly a slight drop of the needle to the east at totality, the horizontal force diminished slightly but no change could be noticed in the vertical force.

At the observations at Meanook, Alberta, no results of note were obtained.

Mr. F. T. Stanford then gave some interesting notes from the January magazines. He mentioned the new planet first observed at Heidelberg and the observations later confirmed at various observatories in the States There was a note about the twenty foot mirror in construction at Paris, which is the largest ever attempted.

Rev. T. R. Phillips in a paper given before the British Association announces the discovery of black moving patches on the moon which are not shadows and hence claims the probability of some low form of life or vegetation on the moon. Prof. Pickering suggests swarming locusts as an example of such life. Mr. Stanford also mentioned Prof. Eddington's announcement that the companion star of Sirius has a density 2,000 times greater than any known earthly substance.

Dr. R. K. Young explained briefly the importance of the planet Eros in getting accurately the distance of the sun from the earth. This planet has a close approach to the earth in 1931 and preparations to measure its distance have already begun.

Mr. J. R. Collins suggested several observations which might have been made at the time of the eclipse. It might have been possible to observe such phenomena as changes in the wind and the clouds, the direction of approach of the shadow, shadow bands on the clouds, flashes on the clouds on second and third contact, and whether the light came back steadily or in pulsations.

The meeting adjourned at 10 p.m.

March 10, 1925.—The regular meeting of the Society was held in the Physics Building, the Vice-President, Mr. Hunter, in the chair.

The minutes of the last meeting were read and approved. Mr. N. H. Schroder, of Penotis, Wis., was nominated for membership in the Society. It was moved by Mr. Gore, seconded by Dr. Young that the by-law requiring nomination to be two weeks before election be suspended and that the secretary cast a ballot in favor of the election of the candidate along with the two nominations received at the last meeting.—Mr. O. S. James, 93 Isabella St., Mr. L. M. McKenzie, B.A., Knox College. The motion was carried.

Mr. Hunter remarked that Mercury will reach its greatest eastern elongation on the 31st of March and should be easily visible as an evening star in the next two or three weeks. He then described the earthquake which occurred on February 28th. The waves came from the east and the motion was sufficient to stop the pendulums of clocks, especially those swinging in the north and south directions. The seat of the disturbance seems to be found in a series of volcanic cores, probably the oldest in the world, which extend for about five hundred miles eastward from the Saguenay River in Quebec. Their extreme age and solidity would account for the fact that the quake was not intense even at its centre, but was felt over a very large area.

Mr. Wm. Gore mentioned having observed a sun pillar about the end of February, the sun being five or six degrees above the horizon and the pillar about fifteen diameters of the sun in extent.

The lecture of the evening was given by Mr. John Patterson, his subject being "What we know about storms". Practically the first correlation of meteorological knowledge was effected by Halley, who commenced charts of winds. The next advance came with the discovery of the barometer, but it was

not until the arrival of the telegraph that any progress was made on the subject of storms. A storm is represented on a chart by a series of circular or elliptical figures drawn through points of equal pressure, a number of such lines close together indicating great pressure change in a small area. Winds are then present in a direction in general tangential to these circular lines.

Mr. Patterson showed slides giving the pressure distribution for various types of storms. The most intense storms are confined to the tropics, the cyclone being a storm on the sea with an area in the centre about fifty to one hundred miles in width, toward which the wind and waves converge from all sides and from which a ship has little chance of escape. The tornado is a storm on land of greater intensity, its danger zone being only about a mile or less in width. The damage in the latter storm is generally caused by the great change in pressure rather than by the wind itself. A thunderstorm has a construction similar to the tropical cyclone, but may have an extent of a thousand miles or more and is accompanied by high wind and heavy rain, snow or hail. We may have a succession of short storms or a storm may remain for days.

In recent times a research has been commenced to find the distribution of pressure on a vertical plane by the use of kites, balloons and other devices. It had been thought that with a certain distribution of pressure on the surface of the earth a similar distribution would obtain for the upper atmosphere. The reverse was found to be the case, the temperature decreasing more rapidly over an area of low pressure than over one of high pressure.

The source of all the energy that produces these storms is found in the water vapour, which is taken up into the atmosphere by evaporation. During a rain, a tremendous amount of energy is poured into the air and serves to keep the storm going. To evaporate enough water to produce one inch of rain over 50,000 square miles would require the consumption of one billion tons of coal, which demonstrates the impossibility of articial production of rain fall.

Sir Napier Shaw conceived the idea of analysing the condition of the atmosphere to find whether it is in a stable condition. It is hoped that this may be of importance in forecasting.

After some discussion, the meeting adjourned at 10 p.m.

The regular meeting of the Society was held in the Physics Building of the University, on March 28, at 8 p.m. Mr. F. Hunter in the chair.

The minutes of the last meeting were read and approved.

The assistant-librarian reported having received 153 periodicals during the months of January-February.

Mr. Hunter remarked that Mercury is visible during the next two weeks and is particularly favourable for observation at this time of the year.

The speaker of the evening was Mr. S. C. Brown, whose subject was "Telescopes and their construction." Mr. Brown remarked that comparatively few people possess telescopes chiefly on account of their high price. To produce a telescope to use in ob erving considerable expense is involved, owing to the difficulty in obtaining glass of the proper density and purity, and to the care and labour necessary in grinding and polishing this glass.

Mr. Brown described in detail a method which he has used by which, with comparatively little expense, a mirror may be made which produces very fair results. The work is done in a room which should be kept at constant temperature. A piece of glass is obtained and mounted on a handle. The grinding tool is fixed on a barrel and the grinding is done by three motions—a motion backwards and forwards across the tool, a rotation of the glass in the hands, and a motion around the barrel. The grinding is then continued using various grades of carborundum until the desired focal length is obtained. Mr. Brown then described the method of polishing and concluded his address with an account of refracting telescopes.

Miss E. M. Budd read various extracts from the astronomical magazines and periodicals of the preceding month, more especially with respect to some of the new large telescopes which are under construction. From the Bulletin of the Astronomical Society of France she read Camille Flammarion's views on the origin of life.

The meeting was adjourned.

At Victoria, B.C.

January, 20, 1925.—The first regular meeting of the Victoria Centre for 1925 was held in Victoria College at 8 p.m. The President, Mr. J. Duff, occupied the chair.

Mr. W. E. Harper gave a short talk upon the 1925 Observer's Handbook, explaining how to use the tables and data for the observations of eclipses, occulations of stars by the moon, the times of sunrise and sunset, planetary phenomena, etc. Attention was called to a new table in this year's Handbook, giving the positions, magnitudes, spectral types, proper motions, radial velocities and distances of the 260 brightest stars.

The President then asked Mr. F. Napier Denison, Director of the Meteorological Observatory, to give the address of the evening upon the subject "Recent Abnormal Cold Weather in British Columbia". The following is a brief summary of the lecture: The records show that the cold weather experienced last month was the most prolonged cold spell since 1874. Slides showing the daily maximum and minimum temperature curves during December of 1874 and of 1924 were explained by the lecturer. The curves were in general similar, being characterized by a sudden drop of some 15 to 20 degrees, a continuance below freezing during the greater part of the month, and a slow recovery to the normal temperature. The 1874 curve showed that the weather was below freezing from Dec. 6th to 31st, over 25 days, the lowest temperature recorded being + 8 degrees. In 1924 the weather was below freezing from Dec. 13th to 27th, about two weeks, the lowest recorded temperature being + 12 degrees.

By a series of daily weather maps Mr. Denison traced the developments of the area of high pressure which formed over Eastern Siberia during the first days of December. This "high", as it is termed, moved westward over North

America. The "polar front" of this area expanding southward and accompanied by temperatures of 40 degrees below zero swept rapidly through the prairie provinces and with progressively higher temperatures, through the middle states. The isobaric lines on the maps were seen to be crowded closely together, indicating a great difference in pressure. This blizzard struck Victoria on the 13th from the North East, the wind having a velocity of 53 miles per hour. In California, temperatures of 5 and 6 degrees of frost were general and caused considerable trouble to the fruit growers. The frost line extended to the shores of the Gulf of Mexico.

Selected maps of the years 1916 and 1924 exhibiting interesting weather conditions were also explained.

A vote of thanks was moved by Mr. Harper, seconded by Prof. P. H. Elliott, and carried unanimously.

February, 17, 1925.—The Victoria Centre of the Society met in Victoria College at 8.00 p.m., the President, Mr. J. Duff, occupied the chair. Attendance approximately fifty.

The following were elected members of the Society:—H. H. Plaskett, Dominion Astrophysical Observatory, Victoria, B.C.; Thos. J. McGill, 349 Foul Bay Rd., Victoria, B.C.

The President spoke briefly of the course of popular lectures on the solar system to be given during the remainder of the Spring Term, and then called upon Mr. W. E. Harper to give the first lecture of the series, upon the subject "The Sun".

The lecturer opened his address by giving data as to the sun's distance and its dimensions and density. The method of determining the sun's distance is based on a modification of the method of triangulation adopted by the surveyor to obtain the distance to inaccessible points on the earth's surface. He instanced the favourable opportunity afforded by one of the asteroids in 1931 for making a new determination for which several observatories are already making preparations. Illustrations such as an airman flying 100 miles an hour and requiring over 100 years to cover the distance to the sun were helpful in bringing home to the audience a conception of the distances and dimensions involved.

From a brief suggestion of our sun as one of millions such in the universe and of its motion through space at 12 minles per second, the speaker passed to a general description of the central luminary.

The temperature of the sun at its surface is 6000° C. Its output of energy has been carefully determined the past two decades and the "solar constant" of radiation is found to be 1.95. If the sun's rays were utilized to melt ice and were unobstructed, then a block of ice 426 feet thick exposed at right angles to the sun's rays would be melted each year. Only a small part of the sun's radiation comes our way and as it radiates equally in all directions its total output is 2,200 million times as much as received by the

earth, a quantity equalled by the yearly combustion of 60 earths if composed of anthracite coal. The speaker showed how the heat in coal, wood, oil and gas is simply the stored up solar energy of past ages.

The elements found to exist in the sun by analysing the sun's light by a spectroscope and comparing with the analysed light of terrestrial substances are 38 in number, as compared with about 86 on the earth. The more common metals, iron, copper, nickel, zinc, lead and tin are well represented, but there is some uncertainty as to the existence of the heavier metals, such as gold, platinum and uranium. These may lie too deep down in the surface for their glowing vapors to be recorded by the spectroscope. All matter is in a gaseous condition at this high temperature.

The structural divisions of the sun were dwelt upon. The photosphere is the main clear cut disk. Over it lies a thin reversing layer of gas cooler than that immediately below. The glowing chromosphere over this again composed of the lighter gases may be likened to a permanent atmosphere. The outlying corona extending for a million miles from the sun is so faint as to be visible only at the times of a total eclipse. It consists largely of matter in the most finely divided state blown off by the intense heat and light pressure from the sun.

Photographs were shown of the sun spots which the speaker described as giant volcanoes, generally occurring in pairs, on the sun's surface. The tiny electrified particles of matter projected outwards from these eruptions at enormous velocities sometimes reach the earth and their bombardment of our upper atmosphere causes the glow we speak of as the "Northern Lights". Beautiful views were also shown of the prominences, the flaming jets of hydrogen, 50,000 to 100,000 miles high, as they passed over the sun's limb and were outlined against the background of the sky.

The speaker in concluding, dwelt briefly on the theories to account for the maintenance of the sun's heat. The falling into the sun of meteors was not favoured as the number necessary would increase the mass of the sun so much that the length of our year would be changed. A contraction of the sun's diameter of 250 feet yearly would compensate for the loss by radiation and this theory has no valid objections. If we knew of the existence in the sun of radio active substances then the energy released by the transmutation of such elements would well explain the prodigious output of energy.

Though the sun is on the descending branch of its curve as regards its life history it is considered good for hundreds of thousands of years yet.

After the lecture a short discussion on radiation took place.

F. Napier Denison moved a vote of thanks to Mr. Harper, which motion was seconded by E. E. Blackwood.

March 3, 1925.—The Society met in Victoria College at 8.00 p.m. The President, Mr. J. Duff, occupied the chair.

The minutes of the meeting of Feb. 17 were read and confirmed.

The President answered several queries regarding the planetary configurations of the present month. He then called upon Prof. P. H. Elliott, of Victoria College, to give the second lecture of the series on the Solar System entitled, "The Moon and Eclipses".

The lecturer first discussed the real motion of the moon in its elliptic orbit about the earth, pointing out that the moon is slightly in advance of its predicted place. This secular accelaration in longitude cannot be accounted for by the theoretical astronomers upon the basis of Newtonian mechanics. The diurnal motion of the moon due to the earth's rotation; the variation in the times of rising and setting and the changes in phase due to its revolution about the earth were then clearly explained. A series of photographs taken with the great equatorial of the Lick Observatory and showing the principal phases was exhibited.

By moving about a table Prof. Elliott demonstrated to the audience that the moon rotates upon its axis once in a sidereal month, and therefore, is constrained to present the same face to the earth. The extent of visible surface, however, is more than 50% for with reference to the earth's centre the moon's face is continually slightly oscillating, these oscillations constituting what is known as the libration. Due to the Diurnal Libration, the Libration in Longitude and Libration in Latitude an additional 9% is sometimes seen, leaving 41% of the lunar surface which we cannot see.

The lecturer spoke at some length upon the surface marking, describing the large dark areas or seas, the high mountain ranges and isolated peaks, the peculiar craters and cracks or rills. A splendid series of selected slides showed the more interesting features. Of the two theories to account for the craters, the volcanic theory is more generally accepted as the meteoric or bombardment theory presents many difficulties.

In consequence of the moon's small mass, about 12/1000 of that of the earth, its gravitational attraction is small, the critical velocity of escape for gases being 1.48 M.P.S. As this value is exceeded by most of the gases, the moon has not been able to retain its atmosphere, or water vapour if it once possessed them. The resulting conditions on its surface were discussed.

In conclusion Prof. Elliott explained by a diagram how the three kinds of eclipses are produced.

A short discussion followed, and a vote of thanks was conveyed to the lecturer.

One query, "How fast does the moon's shadow move on the earth's surface?" was answered by the Secretary.

The meeting adjourned at 9.30 p.m.

March 17, 1925.—The Society met in Victoria College at 8.00 p.m. The President, Mr. J. Duff, occupied the chair. The attendance was about forty.

The minutes of the meeting of March 3 were read and confirmed.

The address of the evening was given by Mr. R. G. Miller, on the subject "The Story of the Earth", being the third lecture of the series, "The Solar System".

The lecturer introduced his subject by speaking of the critical, undogmatic and receptive habit of mind, the scientific attitude, which is becoming more and more general. The growth of our knowledge regarding the origin, evolution and climatic changes of the earth is a striking illustration of how ideas based upon dogmatic interpretations of old legends have been replaced by modern conceptions founded upon deductive reasoning. The older views of a flat-earthed, geocentric universe were contrasted with the present day conception of the great stellar universe in which the sun itself plays so unimportant a part.

The four theories which have been advanced to account for the formation of the solar system were reviewed and, while pointing out their relative merits, the lecturer reminded the Society it was best not to hold a decided preference since all present difficulties.

Following a brief description of the atmosphere, hydrosphere and lithosphere Mr. Miller described the continual erosion of the mountains by the weather agents, showing that the wearing away of the high lands by the rivers and rains and the subsequent depositing of many hundreds of millions of tons of soil annually upon the sloping shelf at the bottom of the sea near the shore causes, after long eras, a fall in the ocean floor under the load and an inward pressure on the crust of the earth, resulting in the formation of new mountain ranges. The elevation of these newly formed ranges and consequent thinning of the atmosphere produces an ice age which lasts until the mountains have again been reduced, so that glacial conditions no longer occur, for with the vanishing of the hills the warmer lowland interglacial age (like the present) results and lasts until another crisis in the crust appears.

The five great geological eras, with their associated Ice Ages and the problematic conditions of life on the earth during each era, were discussed by the speaker, who in concluding his brief review of biological evolution quoted the following from Huxley:—

"If it were given to me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions which it can no more see than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter."

A discussion of the lecture was participated in by a dozen members. While not reporting the speakers verbatim, the Secretary wishes to place on record three findings of the discussion in which he believes all speakers agreed.

(1) The Story of the Earth's formation, its geological and biological evolution as described by the lecturer must be accepted as the closest approximation we have to the truth, as it represents the convictions of those men who have

devoted their entire lives to the subject and who are most qualified to interpret the scientific evidence and deduce rational conclusions.

(2) This thesis, that the earth was created and life evolved in this way does not preclude the existance of or authorship of a Supreme Being, the Architect of the Universe.

(3) Science, because of the very nature of its methods, must leave a discussion of the Deity to the provinces of Religion and Philosophy.

The meeting adjourned at 9.45 p.m.

J. A. PEARCE,
Secretary.

At Montreal

March 25, 1925.—The President, Justice E. E. Howard in the chair.

The minutes were taken as read.

New members were elected as follows:

Mr. J. Farmer, Montreal; Mrs. W. Bigg, Montreal; Miss M. O. Vaudry, Lennoxville.

The president invited further applications for membership and then introduced the speaker of the evening, Dr. Benjamin Boss, of Dudley Observatory, Albany, N.Y., whose subject was Stellar Motions and the Structure of the Universe.

Dr. Boss stated that the object of the astronomer is twofold, first, the study of the structure of a star, its birth and life history, and secondly, the structure of the universe. This latter involves a study of the disposition of the stars in space and their motions.

The statistical method of attack is based upon the assumption that on the average when a very great number of stars are considered, those that are the brighter are nearer the sun than the fainter stars, and likewise those with the larger proper motions are nearer than those with little or no measurable proper motion. The work of Kapteyn and van Rhijn about 1920 led to a Luminosity Law which indicated that just as there are relatively few very bright stars so there are fewer and fewer very faint stars as we pass beyond 8th magnitude, the most probable magnitude being in the neighbourhood of 3rd or 4th.

Utilizing more recently accumulated data, Seares has revised this work and finds the Luminosity Curve to rise again for the fainter stars rather than to fall off steadily as Kapteyn had been led to believe.

On the other hand the Density Law as obtained by Kapteyn and van Rhijn has been essentially confirmed by the recent work of Seares, the number of stars that can be counted in an arbitrarily chosen volume of space decreasing progressively as we pass outwards from the sun, this decrease being much more rapid in the direction of the galactic poles than in the plane of the galaxy where the Milky Way spreads out some 10,000 parsecs from the sun.

Attempts to determine the Solar Motion both in direction and magnitude are based upon finding the average apparent star drift both in proper motion and radial velocity. The resultant drift is then considered to be due to a

motion of the sun in the reverse direction at that average speed. This direction, or Apex, is found to be between the constellations of Hercules and Lyra, but when determined from the motions of massive blue stars the galactic longitude of the apex is not as great as when determined from the less massive, high velocity, red stars.

Kapteyn interpreted this systematic difference between the average velocities of two groups of stars as indicative of the existence of two distinct star streams. This Two Drift Theory seemed to have much in its support, but has been opposed by Schwartzschild who has developed the Ellipsoidal Theory to account for the observed velocities.

If from a point in space a vector be drawn for each star representing its velocity in direction and magnitude, and if surfaces be then drawn connecting the extremities of the vectors of stars belonging to different classes (these classes roughly corresponding to the masses of the stars), then the surfaces so formed are found by both Schwartzschild and Strömberg to be ellipsoids whose centres of symmetry, from smallest to greatest, have been progressively displaced along one of the two minor axes oriented towards the constellation of Orion. The major axis is directed to a point in space lying between the constellations of Serpens and Aquila, its exact location depending on the ellipsoid considered which corresponds to the group of stars selected, as in the case of the position of the Apex.

The preferential motion of the stars in the direction of this major axis has led the lecturer and other astronomers to speculate as to the nature of the force, evidently external to our galaxy, which is at work upon it. Their thoughts turn to the facts gradually being obtained by van Maanen, Hubble and others, with regard to the distances of the spiral nebulae and the motions along the spiral arms of the star condensations. Considering also the fact that the Apex, as determined from radial velocities of the spirals, is displaced even more than when determined by the high velocity stars, and in the same direction, the question presents itself as to whether there may be some great influence at work upon the whole universe, upon the spirals and likewise upon the stars of our own galaxy which itself resembles a spiral nebulae in so many respects.

If there were a condensation of spiral nebulae or star clusters in the direction of this preferential motion, a gravitational explanation might appear plausible, but no such condensation has been observed and thus the astronomer is faced with a great mystery.

The forces within our galaxy will not suffice to account for the motions of the stars; some vast cosmic force is at work, but whence it originates and what may be its full significance are queries to which as yet there are no replies.

After a few remarks by the President a warm vote of thanks and appreciation was tendered the speaker.

The meeting adjourned.

A. VIBERT DOUGLAS,
Secretary.

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